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DESIGN AND EVALUATION OF A FACILITY TO STUDY TWO-DIMENSIONAL SU--ETC(U)
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DESIGN AND EVALUATION OF A FACILITY
TO STUDY TWO-DIMENSIONAL
SUPERSONIC AIR-HELIUM MIXING

THESIS

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Preface

This study was the result of continued interest in the development of high energy lasers. This is a continuation of previous efforts by Dr. A. J. Shine of the Air Force Institute of Technology.

This report describes the results of my efforts in the design, construction, and experimental use of a multiple nozzle flow device. The experimental portion of this report is a brief investigation of the flow characteristics which result when air and helium are used in the flow device at three representative flow conditions.

I wish to express my appreciation to Dr. Richard A. Merz, my faculty advisor, whose door was always open to hear my problems and offer sound advice. I wish to thank Drs. William C. Elrod and Harold E. Wright for their valuable advice which helped me over several trouble spots. I sincerely appreciate the skillful work and craftsmanship of Mr. Carl Short and the members of the AFIT Model Shop who fabricated the many components of the apparatus. The assistance of Mr. William Baker and Mr. Harold Cannon was vital to the assembly and operation of the apparatus in the laboratory. And finally to my fiancee, Miss Janette Rolfe, for her help in recording hundreds of manometer readings from photographs and for her patience and encouragement.

John D. Carlile

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K	Specific heat ratio
L	Axial distance downstream from the nozzle exit plane
M	Local Mach number
P	Local static pressure
P_t	Local total pressure
$P_{o\ Air}$	Air chamber stagnation pressure
$P_{o\ He}$	Helium chamber stagnation pressure

Abstract

A facility to study two-dimensional supersonic air-helium mixing in a gas dynamic laser cavity was designed, constructed, and evaluated. The flow field may be analyzed via static and total pressure measurements, gas mixture samples, and schlieren photography. The multiple nozzle test section consisted of Mach 3.0 air nozzles alternated with Mach 3.0 helium nozzles exhausted into an instrumented test cavity. Pressure was maintained in the cavity by two alternate methods; simple diffusers exhausted to atmospheric conditions, and exhausting the cavity into a group of evaculated air tanks. Both methods gave similar cavity flow fields as indicated by schlieren photography and static pressure measurements. Gas samples and pressure measurements were taken with a series of small diameter probes and automatically timed solenoid valves. Gas samples were not analyzed in this study. Nozzle exit plane Mach numbers were calculated from pressure measurements and verified with schlieren photographs of a wedge inserted into the flow. The apparatus has low helium consumption and yields accurate, repeatable pressure measurements. The facility is to be used for a subsequent complete flow field analysis.

DESIGN AND EVALUATION OF A FACILITY TO ANALYZE TWO DIMENSIONAL SUPERSONIC MIXING

I. Introduction

Background

Operation of the high energy gas dynamic laser is based on the rapid expansion of high energy gases through an array of short supersonic nozzles. After rapid expansion the molecular vibrational energy cannot relax rapidly enough to maintain Boltzman equilibrium, creating a molecular population inversion (ref 1). As the molecules subsequently relax to a stable energy level, they may be induced to release energy in the form of photons. This photon release is referred to as lasing.

To obtain a high lasing energy output requires a large population inversion which in turn requires a high mass flow of the working medium. Although mixing of the different gases may occur either before or after expansion, potential advantages in efficiency exist when mixing occurs after expansion (ref 2).

Purpose

The purpose of this study was to design and evaluate a facility to investigate the mixing and flow characteristics of a two-dimensional multiple nozzle configuration designed by Dr. A. J. Shine in conjunction with the Air Force Weapons Laboratory, Kirtland AFB, New Mexico. The nozzle design consisted of Mach 3.0 helium nozzles sandwiched between Mach 3.0 air nozzles. Figure 1 shows the nozzle configuration.

Scope

The extent of this study was limited to: (1) comparison of the flow field at a variety of stagnation pressures using schlieren

photography and static pressure measurements with the cavity exhausted into diffusers and atmospheric conditions and with the cavity exhausted into a vacuum source; (2) development of a method of sampling the gas mixture at several locations across the flow and downstream of the nozzle exit plane; (3) development of a method of measuring both static and total pressures at the sampling locations; and (4) a brief evaluation of the flow field at three representative flow conditions.

This study did not address: (1) variation of specific heats; (2) boundary layer effects; (3) variation of inlet temperatures; (4) analysis of sampled gas mixtures; and (5) extensive flow field analysis.

Assumptions

The following assumptions were made for this study:

1. Air and helium obey the perfect gas laws.
2. The nozzles were isentropic.
3. Velocities in the respective stilling chambers were approximately zero.

II. Apparatus

The experimental equipment consisted of a test section with a multiple nozzle assembly, an air supply, a helium supply, a vacuum system, a schlieren system, a gas sample collecting system, and instrumentation. The arrangement of the apparatus is shown in Figure 2.

Test Section

The test section consisted of the nozzle assembly, test cavity, and removable diffusers. The test section is shown in Figure 3 and Figure 4.

The nozzle assembly consisted of three air nozzles sandwiching two helium nozzles. Aluminum nozzle blocks formed two-dimensional nozzles designed to allow the respective gases to accelerate to a theoretical exit Mach number of 3.0. The air nozzle had throat dimensions of 0.133 by 0.375 inches and exit dimensions of 0.563 by 0.375 inches. The helium nozzle had throat dimensions of 0.095 by 0.375 inches and exit dimensions of 0.286 by 0.375 inches. Helium was injected into the nozzle blocks from both sides by 0.375 inch tubing.

The nozzle depth of 0.375 inches was less than ideal for schlieren photography but was used to reduce helium consumption and prolong run times with the blowdown vacuum system.

The test cavity was 7.0 inches long, 2.375 inches wide, and 0.375 inches deep. The sidewalls were clear plexiglass 10.5 inches long, 4.4 inches wide, and 0.75 inches thick. One sidewall was equipped with static pressure taps at the nozzle exit plane of the center air nozzle and one of the helium nozzles as shown in Figure 1. That sidewall

remained in place for all tests. Two sidewalls were used for the opposite side. A clear plexiglass sidewall was used for schlieren photographs. A plexiglass sidewall with 36 static pressure taps and 36 openings through which probes were inserted into the flow was used for gas sampling and pressure measurements. The location of the pressure taps is shown in Figure 5.

The removable diffusers had a ramp angle of 12 degrees and a ramp height of 0.15 inches. They were in place for tests exhausting to atmospheric conditions and removed when using the vacuum system.

Air Supply

A 100 HP Worthington air compressor was used to supply the air at a pressure of 110 psig. After leaving the compressor, the air was filtered, dried, and stored in a supply tank until ready for use. A three-inch supply line with a gate valve and hand operated slide valve regulated the air to the stilling chamber. The air was then refiltered in the stilling chamber.

Helium Supply

The helium was supplied by 12 high pressure cylinders connected to a common manifold. Two dome regulators were used to control the pressure to the helium stilling chamber and a 0.75 inch hand operated quick acting valve was used to start and stop the flow. The helium was filtered in the stilling chamber.

Vacuum System

One Stokes and two Leiman vacuum pumps were used to evacuate sixteen 250-gallon (33.4 cu ft) storage tanks. The vacuum pumps alone were able to maintain an exhaust plane pressure 5 psi below atmospheric at

the highest mass flow evaluated in this study. The storage tanks were used in conjunction with the vacuum pumps to provide a blowdown type system. Flow into the vacuum system was controlled with a remote actuated eight-inch pneumatic slide valve.

Schlieren System

A schlieren system, shown in Figure 2, was used to view the flow in the test section. A steady zirconium arc lamp light source and frosted glass screen at the focal plane were used for real time flow observations. A spark lamp light source and Polaroid Graphic camera were used to record photographic results. Polaroid film, Type 47, in a 4 x 5 inch format was used for all schlieren photographs. Photographs were taken with the knife edge both perpendicular and parallel to the flow direction. The parabolic mirrors used were 7 inches in diameter with a focal length of 40 inches.

Gas Sample Collecting System

The apparatus used to capture gas samples was an arrangement of nine sample containers and associated valves. Each container had a mechanical valve at each end and a 3-way solenoid valve at the inlet end. The arrangement is shown in Figure 6.

The solenoid valves were used for quick action during the experimental run and the mechanical valves used to allow the containers to be disconnected from the system without losing the sample. The nine solenoid valves were remotely and simultaneously opened by the experimenter and were closed simultaneously by a timed relay to obtain uniform sampling times. A warning light was connected to the relay to indicate when the valves were open.

The vacuum pumps from the vacuum system were attached to the system to evacuate the sample containers prior to each run. This allowed shorter run times and conservation of helium.

Nine probes were inserted into the flow field as shown in Figure 5. The probes were made of stainless steel tubes of two sizes soldered together. The tubes were 0.032 inch outside diameter (.022 inch ID) within the flow field and 0.109 inch outside diameter (.085 inch ID) external to the flow field. Probes were aligned using a 0.172 inch spacer block and a ten power microscope to allow positioning at the center of the test section and parallel to the flow.

Pressure Measurements

The gas sampling probes were also used to measure total pressure within the flow field. The probes were connected to a bank of vertical mercury manometers as shown in Figure 6 in the pressure measurement configuration. A static pressure port was located just below each probe tip and very slightly upstream (.015 inch) to avoid effects of the detached shock wave from the probe tip (ref 3). The gas samples and pressures could be taken at one inch intervals downstream of the nozzle exit plane as shown in Figure 5.

Instrumentation

The air stilling chamber pressure was measured with a 0-200 psig dial gage accurate to ±2.0 psi located upstream of the filters and a 0-160 psig dial gage accurate to ±1.0 psi located downstream of the filters. The upstream gage was used to monitor the condition of the filters based on the pressure drop across the filters.

The helium stilling chamber pressure was measured with a 0-200 in

Hg dial gage, accurate to 0.4 in Hg, located downstream of the filters.

Both stilling chamber temperatures were measured with copper-constantan thermocouples. A Honeywell strip-chart recorder was used to convert the thermocouple output to a calibrated temperature scale. The thermocouples were calibrated in a Fisher Isotherm Bath and a potientiometer was used to calibrate the strip-chart recorder.

Static pressure readings were measured on a vertical bank of 50-inch mercury U-tube manometers. Results were recorded with a 4 x 5 inch format Polaroid Graphic camera using Type 42 Polaroid film. The photographic results were read to an accuracy of 0.1 in Hg using a three power viewing lens.

Total pressures were measured on a similar bank of 50-inch manometers using the 3-way solenoid valves described previously. The U-tubes were connected to allow a preset pressure above atmospheric to be loaded to permit measurement of pressures in excess of 50 in Hg as shown in Figure 7. The solenoid valves were used to minimize the inertial effects of the mercury in the U-tubes by allowing the pressure in the manometer tubes and lines to be held between test runs. Pressure leakage was negligible over a 24-hour period. Readings were taken within minutes of the completion of each test run. This system allowed shorter run times and helium conservation by rapid stabilization of pressure readings.

III. Experimental Procedure

The experimental work was divided into two general areas, optical and pressure measurement studies. The procedure for both was essentially the same.

Prior to each run, the vacuum system storage tanks were evacuated to a pressure of approximately 0.5 psia. The air control valve and helium regulator were set to the desired pressures. The pneumatic vacuum system valve was actuated and as soon as the test section static pressure ports gave a positive indication of the valve opening (2-3 sec), the air flow was initiated. After the air stilling chamber pressure stabilized, the helium flow was initiated. If the test section static pressures indicated stabilized flow, the solenoids were actuated at an indicated vacuum system pressure of 2.5 psia.

For the pressure studies, at the completion of 10 seconds, the timer relay automatically closed the solenoid valves on the total pressure probes and activated the warning light. As the warning light came on, the camera was manually tripped to photograph the static pressure manometer board.

For the optical studies the nozzle exit plane static pressure readings were taken with the solenoid valves and a schlieren photograph was taken after seven seconds. The schlieren photographs were taken with the room darkened and using a remotely fired spark lamp.

The helium and air flows were then terminated and after the air stilling chamber pressure dropped below 10 psig the pneumatic vacuum system valve was closed. Caution was exercised at all times to avoid overpressurizing the plexiglass test section and the mercury manometers.

Prior to each total pressure measurement run, an estimate was made of the maximum total pressure expected. Any preload required on the manometer board was then applied and the valve from the compressed air bottle (fig 7) closed. An emergency solenoid valve shut off switch was monitored during the test run to avoid overpressurizing the total pressure manometer board.

The run was terminated if the air stilling chamber pressure varied by more than ±2 psig. The run was also terminated if the helium supply did not maintain the preset pressure.

IV. Results and Discussion

The purpose of this study was to design, construct, and evaluate a facility to analyze the flow field in a gas dynamic laser cavity. In consideration of this purpose, the following topics are discussed.

Start/Unstart Performance

The test cavity was considered to have started when steady state supersonic flow existed from the nozzle exit to the diffuser entrance plane or the test cavity exit plane. The started condition was observed optically with the schlieren system. Unstart was observed optically and by an abrupt 3 to 5 psi increase in the nozzle exit plane static pressures.

With the diffusers installed and atmospheric exhaust conditions, once the cavity had started it was possible to decrease the stagnation pressures by 5 to 10 percent before unstart occurred. Start/unstart pressures were established by setting a helium pressure and slowly increasing the air pressure until start and then slowly decreasing it until unstart. With no mass flow from the helium nozzles the cavity started at approximately 50 psig. Increased helium mass flow resulted in increased air pressure required for start. At helium pressures of 100 in Hg, air pressures in excess of 90 psig were normally required for cavity start. Extensive tests were not conducted to determine exact starting conditions. The pressures required were very sensitive to rapid changes in mass flow when the pressures were set.

Introduction of the pressure measuring probes into the flow field sufficiently disrupted the flow and diffuser efficiency to make accurate data unobtainable. With helium pressures in excess of 45 in Hg,

the cavity could not be started with the 110 psig air pressure available.

Connection of the vacuum system with the diffusers installed did not significantly increase the performance above that obtained with the cavity exhausted to atmospheric conditions.

With the diffusers removed and vacuum system connected, the start/unstart conditions were a function of stagnation pressures and the pressure existing at the cavity exhaust plane. The vacuum system pressures used resulted in cavity start occurring with air pressures in the order of 45 psig when using a helium pressure of 75 in Hg. The flow field upstream remained stable when the pressure measuring probes were installed. All pressure data presented in this report were taken with this configuration.

Schlieren Analysis

The flow field looks essentially as depicted in Figure 8 for the three test conditions evaluated. The shear layer characteristics change with variation in nozzle exit plane static pressure differential and slightly with variation of air stilling chamber pressure. Figures 9 through 11 show typical schlieren results at the evaluated test conditions.

Schlieren photographic studies were made both with the diffusers installed and with the diffusers removed and exhausting into the vacuum system. The flow field appeared identical upstream of the diffuser entrance plane when identical stagnation pressures existed after cavity start.

Figures 12 through 14 show schlieren results obtained with diffusers installed at test conditions other than the three evaluated in

this report. Good photographic results were obtained at a wide variety of test conditions. Stable flow conditions with essentially the same flow field existed at most test conditions. However, highly unstable flow fields existed with zero helium mass flow as the central air flow attempted to attach to one of the other two air flows.

Shock waves could not be seen in the helium flow. The density of helium is low in relation to that of air. The small test section thickness gave density gradients too small to be visible. A variety of optical filters were tried unsuccessfully in an attempt to visualize the helium shock patterns.

Nozzle Exit Plane Static Pressures

Nozzle exit plane static pressures were monitored and recorded for each test run to identify start/unstart conditions and used to calculate nozzle exit plane Mach numbers for each run (ref 4).

To verify the calculated nozzle exit plane Mach number, a ten degree wedge was positioned at the air nozzle exit plane. Resulting shock angles were measured from schlieren photographs and the exit plane Mach numbers determined (ref 5). The results from the measured shock angles agreed to within six percent of the calculated values from the exit plane static pressures. This was within the accuracy possible with the methods used.

Pressure Variation Within the Flow Field

Static and total pressure data are presented in tabular form in Appendix A. The variation of P_t/P within the flow field at the three test conditions is given in graphical form in Figures 15 through 17. An alternate expansion and compression of the center air nozzle flow

is shown in Figure 8 and the result is shown by Probe #5 on Figures 15 through 17.

Probes #1, #3, #5, #7, and #9 were normalized with respect to their respective nozzle stagnation pressures. The results are shown in Figure 18. At L = 4.0 inches, the data showed significant scatter for all three probes in the air flows, indicating the mixing layer expansion. Comparison of the data in Figure 18 with schlieren photographs (fig 9, 10) verified that the shear layer had penetrated to the centerline of the top (Probe #1) air nozzle. After mixing had occurred the nondimensionalized calculations were no longer valid.

Approximate Mach numbers within the flow field were calculated by assuming that Probes #1, #5, and #9 were in 100 percent air (K = 1.4) and Probes #3 and #7 were in 100 percent helium (K = 1.67). Significant scatter appeared at L = 4.0 inches indicating that some mixing had taken place at those locations. The results are shown in Figure 19. Comparison with schlieren photographs verified the shear layer expansion and mixing. Mixing invalidated the Mach number calculations and resulted in the wide spread of data at L = 4.0 inches.

Data taken at L = 1.0 inches are in error for Probes #9 and #5 due to a slight mislocation of the lower aluminum nozzle block which resulted in a decreased area ratio for the center air nozzle and an increased area ratio for the lower air nozzle.

V. Conclusions

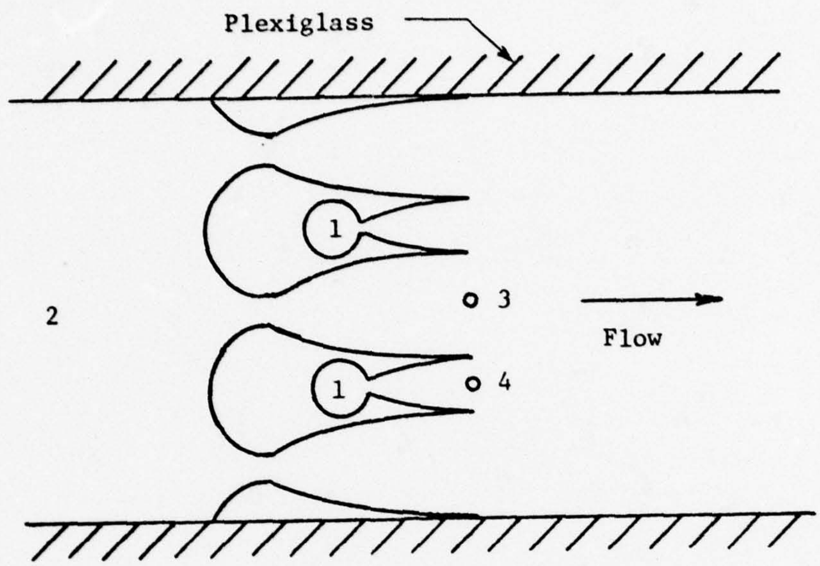
The objectives of this study were to design and evaluate a facility to investigate the flow field in a gas dynamic laser cavity. The following conclusions were reached as a result of this study:

1. The cavity flow field is sensitive to interference effects of the pressure measuring/gas sampling equipment. The installation of three different measuring equipment designs into the flow field was found to give unsatisfactory results when used with diffusers and atmospheric exhaust.
2. The probes described in Section II give satisfactory results when used with the cavity exhausting into a vacuum system without diffusers.
3. The use of a vacuum system in place of diffusers does not alter the flow field upstream of the diffuser entrance plane.
4. Schlieren photography is an aid in evaluating the flow field pressure results but is unsatisfactory for observing shock patterns in the helium flow with the test section dimensions used.
5. The equipment is capable of accurate, repeatable flow field measurements with low helium consumption.

VI. Recommendations

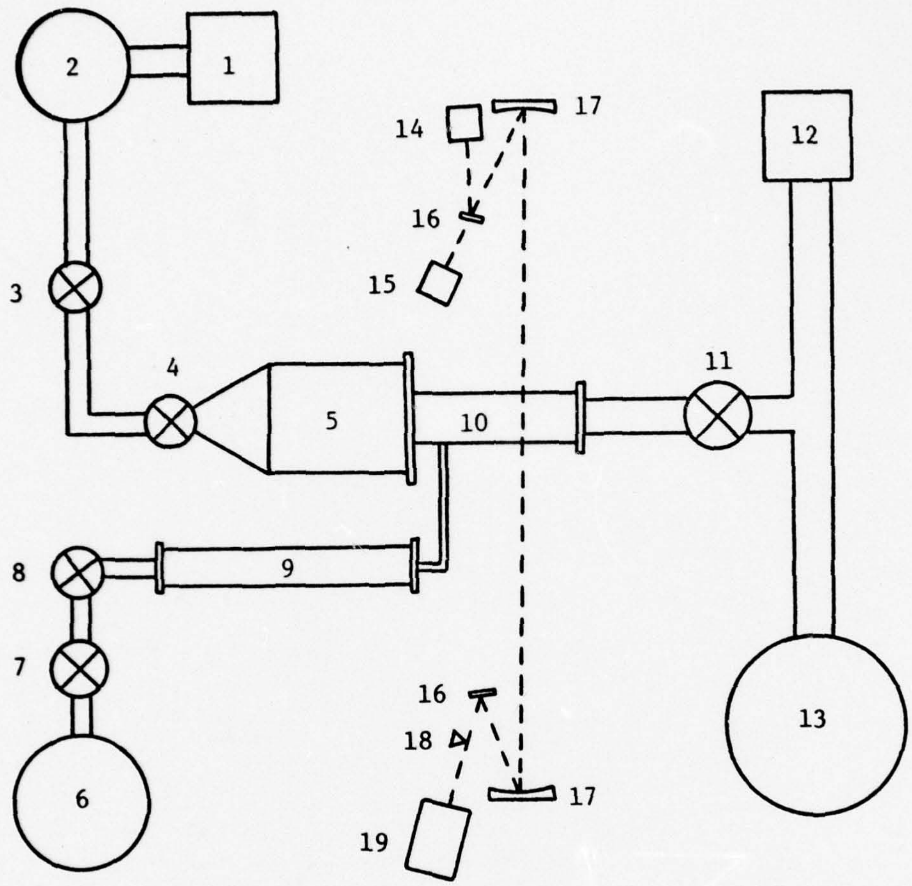
This study did not include a detailed flow field analysis. A subsequent complete analysis using the described facility would be worthwhile. The following are recommendations for future study:

1. Gas samples be taken and concentration profiles evaluated.
2. Comparisons be made between concentration profiles, pressure profiles, and schlieren results to identify the mixing structure.
3. Additional points in the flow field be evaluated, particularly further downstream. Different length probes should be used for sampling intermediate positions.
4. Additional pressures be closely evaluated, particularly those giving a wider range of nozzle exit plane static pressure differential.



1. Helium at Stagnation Conditions
2. Air at Stagnation Conditions
3. Exit Plane Static Pressure Port (Air)
4. Exit Plane Static Pressure Port (Helium)

Fig. 1. Multiple Nozzle Configuration



1. Air Compressors and Dryers
2. Air Storage Tanks
3. Rotary Hand Valve
4. Slide Valve
5. Air Stilling Chamber
6. Helium Supply Bottles
7. Dome Regulators
8. Hand Valve
9. Helium Stilling Chamber
10. Test Section
11. Pneumatic Valve
12. Vacuum Pumps
13. Vacuum Chambers
14. Steady Lamp
15. Spark Lamp
16. Plane Mirror
17. Parabolic Mirror
18. Knife Edge
19. Camera/View Screen

Fig. 2. Schematic of the Test Facility

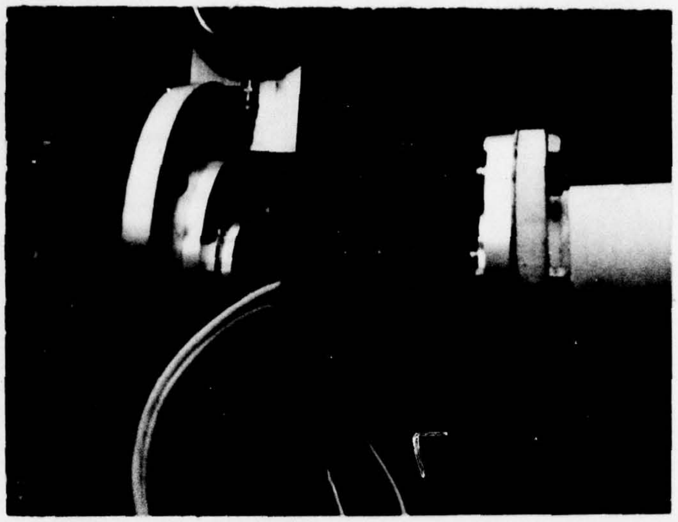


Fig. 3. Test Section

Fig. 4. Test Section with Probes Installed

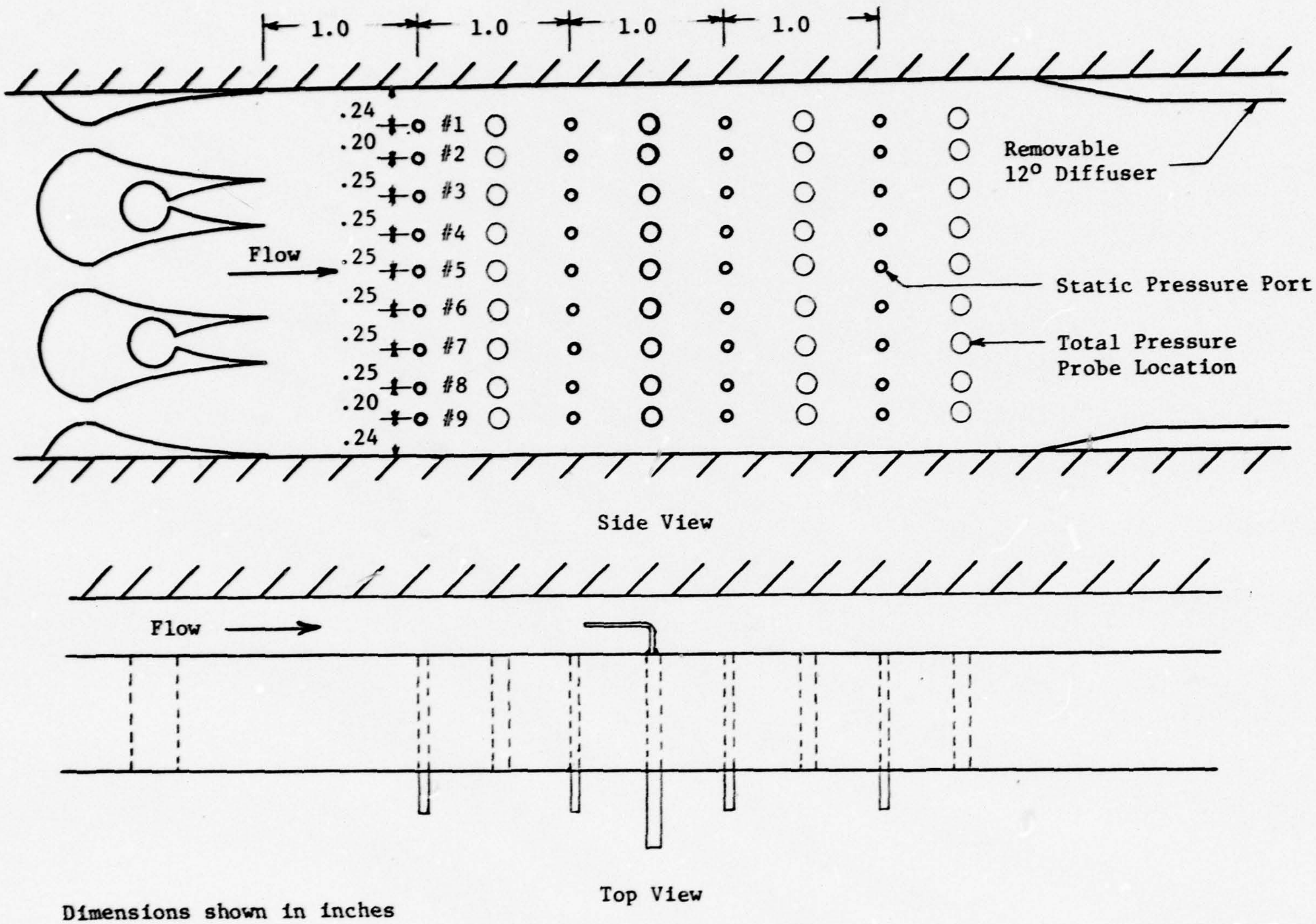
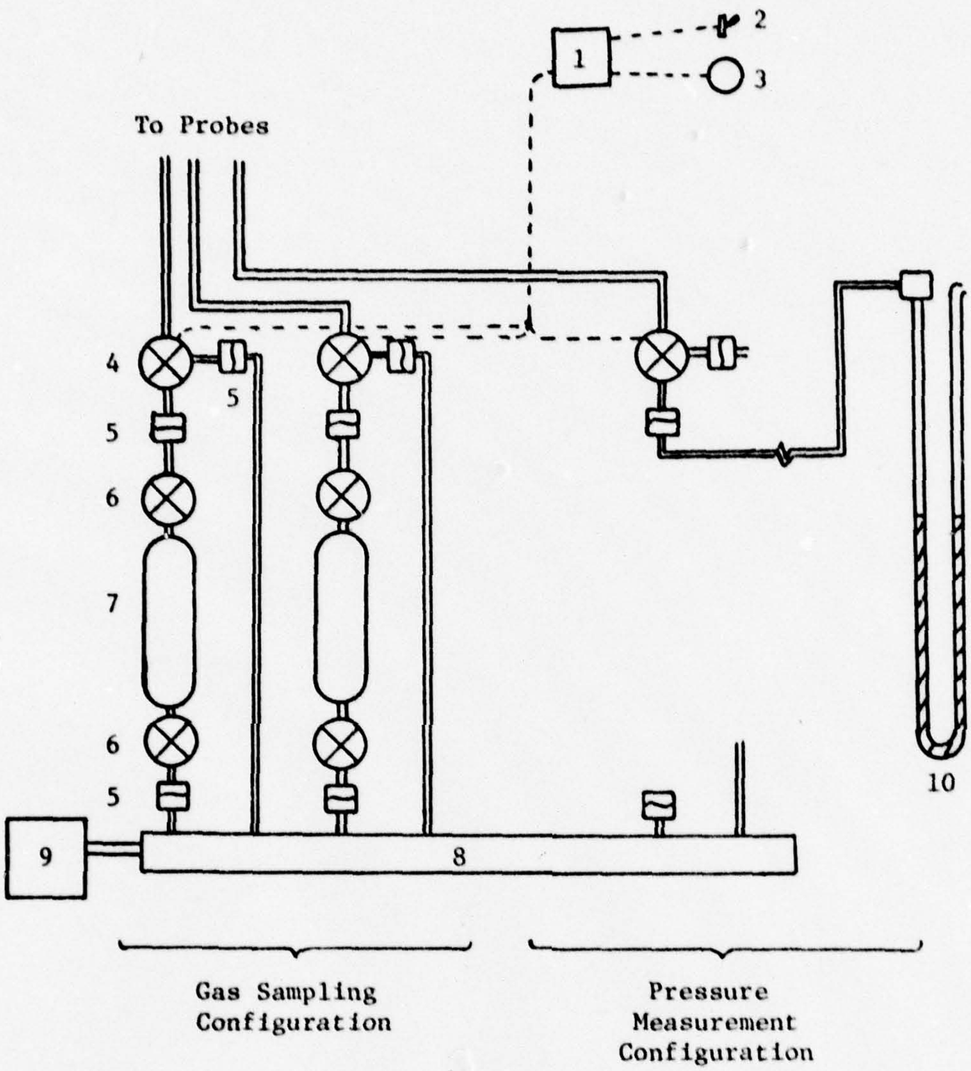
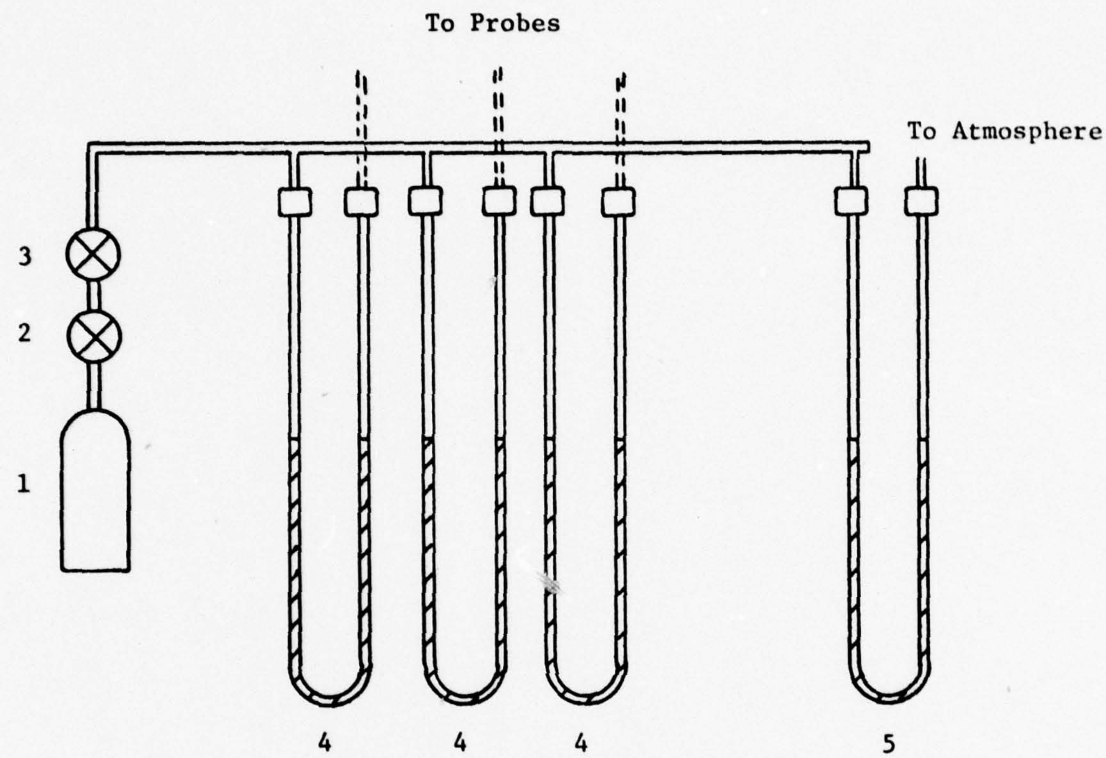


Fig. 5. Pressure Tap Locations



1. Timed Relay
2. Activate Switch
3. Warning Light
4. 3-Way Solenoid Valve
5. Coupling
6. Manual Valve
7. Sample Bottle
8. Manifold
9. Vacuum Pump
10. Mercury Manometers

Fig. 6. Schematic of Gas Sampling Equipment



1. Compressed Air
2. Regulator
3. Valve
4. Loaded Manometer Tubes
5. Reference Manometer Tube

Fig. 7. Schematic of Loaded Manometer Bank

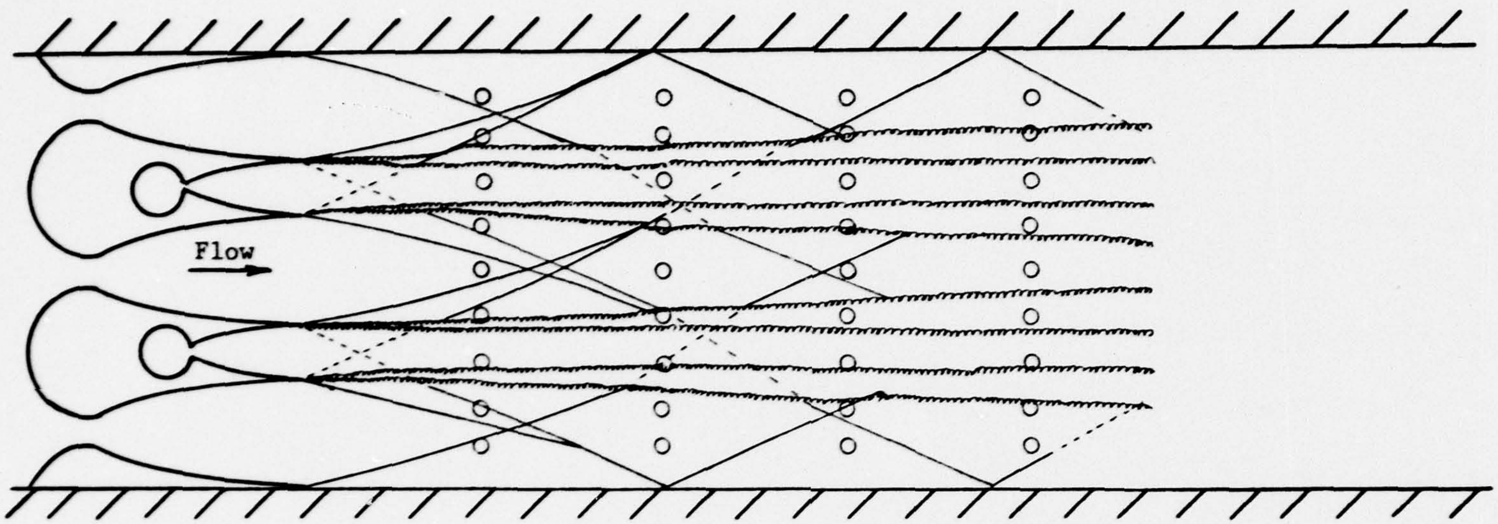


Fig. 8. Flow Field Shock Patterns

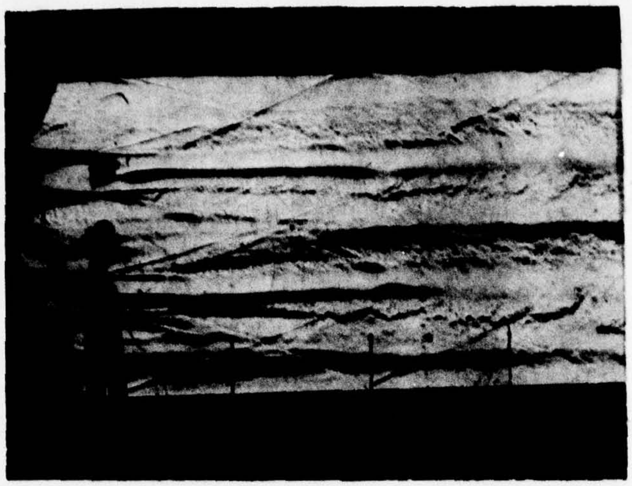


Fig. 9. Schlieren Photograph, $P_{o\ Air}$ = 80 psig, $P_{o\ He}$ = 75 in Hg

Exit Plane Conditions:

Air Nozzle	P = 3.05 psig	M = 2.89
He Nozzle	P = 1.77 psig	M = 2.92

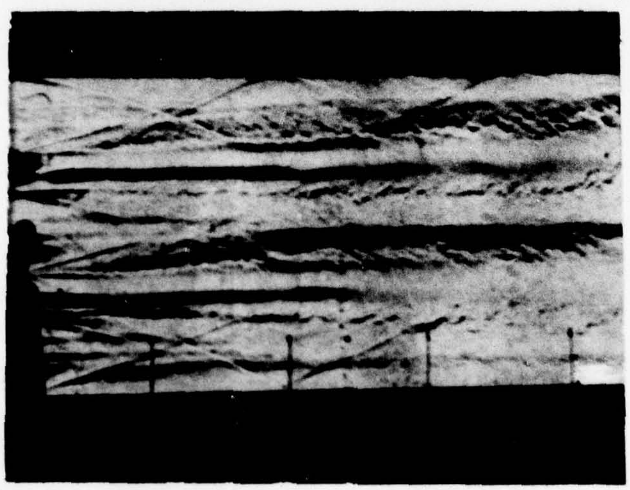


Fig. 10. Schlieren Photograph, $P_{o\ Air}$ = 65 psig, $P_{o\ He}$ = 75 in Hg

Exit Plane Conditions:

Air Nozzle	P = 2.41 psig	M = 2.93
He Nozzle	P = 1.72 psig	M = 2.94

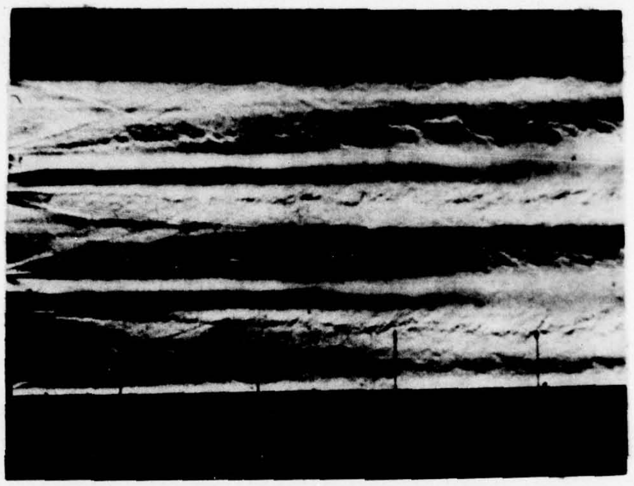


Fig. 11. Schlieren Photograph, $P_{o\ Air}$ = 50 psig, $P_{o\ He}$ = 75 in Hg

Exit Plane Conditions:

Air Nozzle	P = 1.82 psig	M = 2.97
He Nozzle	P = 1.77 psig	M = 2.92

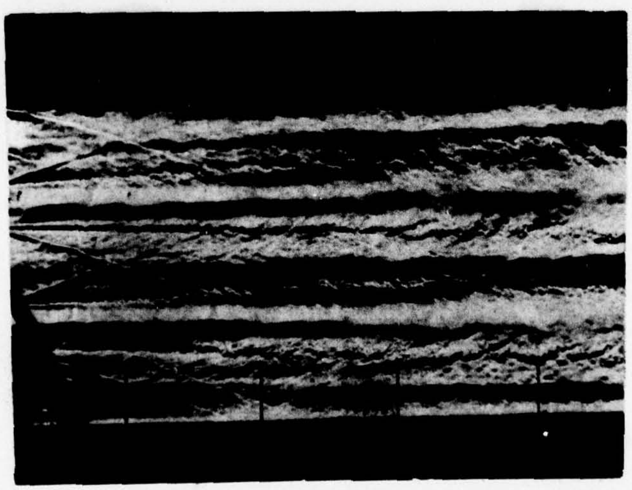


Fig. 12. Schlieren Photograph, $P_{o\ Air}$ = 108 psig, $P_{o\ He}$ = 135 in Hg

Exit Plane Conditions:

Air Nozzle	P = 3.39 psig	M = 2.99
He Nozzle	P = 2.70 psig	M = 2.94

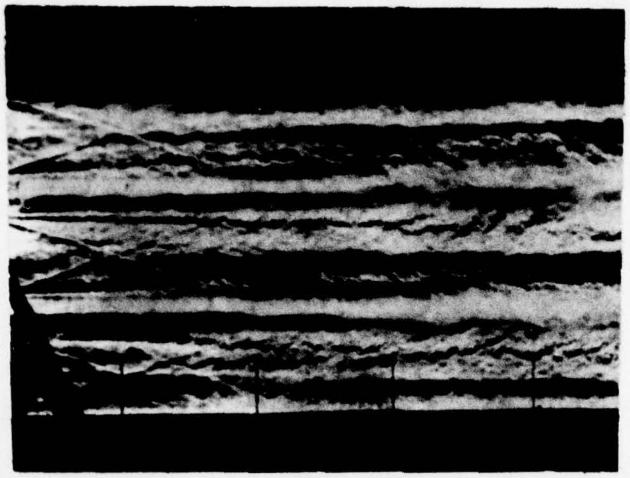


Fig. 13. Schlieren Photograph, $P_{o\ Air}$ = 100 psig, $P_{o\ He}$ = 162 in Hg

Exit Plane Conditions:

Air Nozzle	P = 3.19 psig	M = 2.98
He Nozzle	P = 3.19 psig	M = 2.93

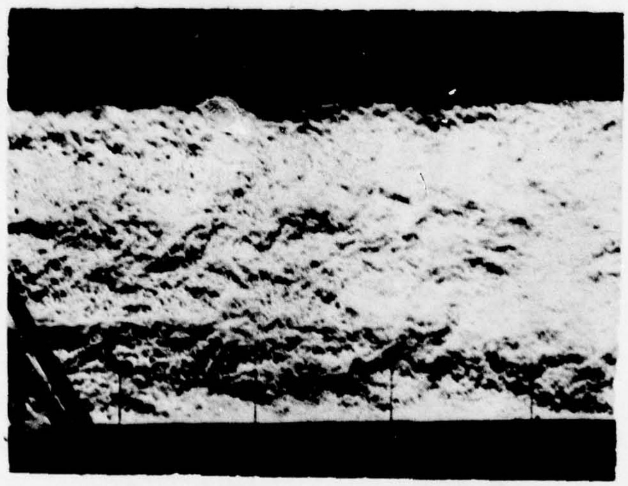


Fig. 14. Schlieren Photograph, $P_{o\ Air}$ = 94 psig, $P_{o\ He}$ = 158 in Hg

Exit Plane Conditions: Unstable

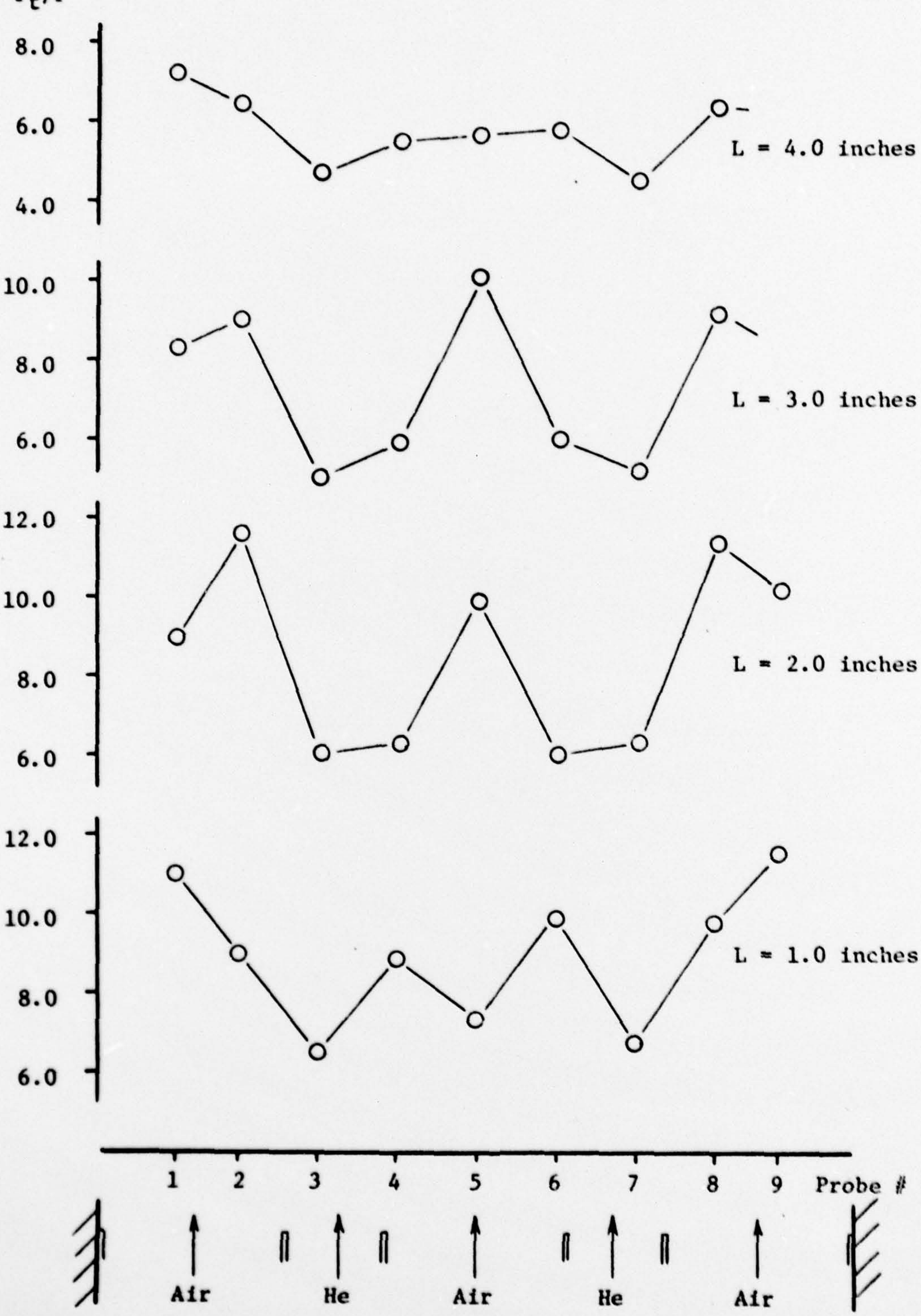


Fig. 15. P_t/P Variation, $P_{o\ Air}$ = 80 psig, $P_{o\ He}$ = 75 in Hg

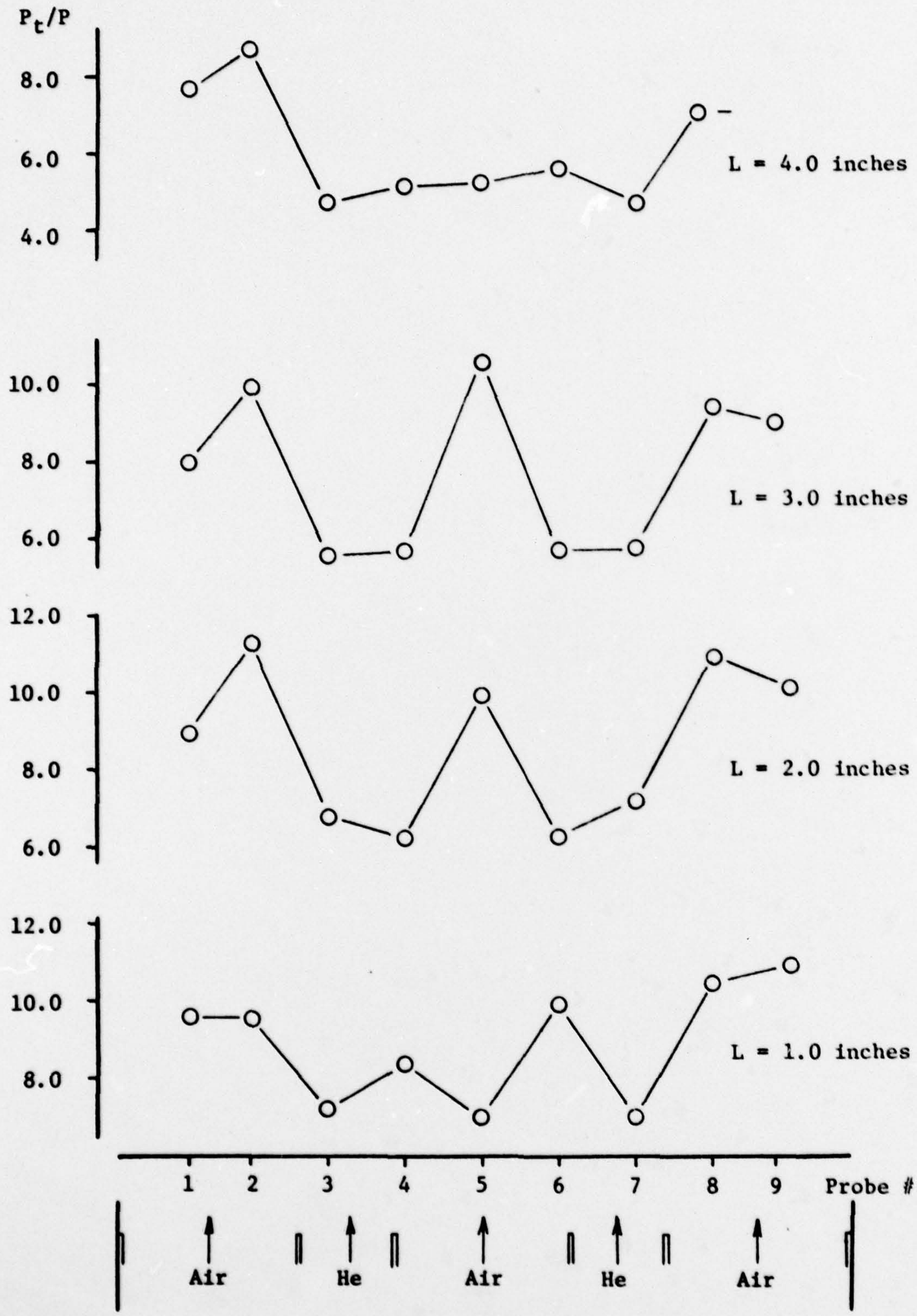


Fig. 16. P_t/P Variation, $P_{o\ Air}$ = 65 psig, $P_{o\ He}$ = 75 in Hg

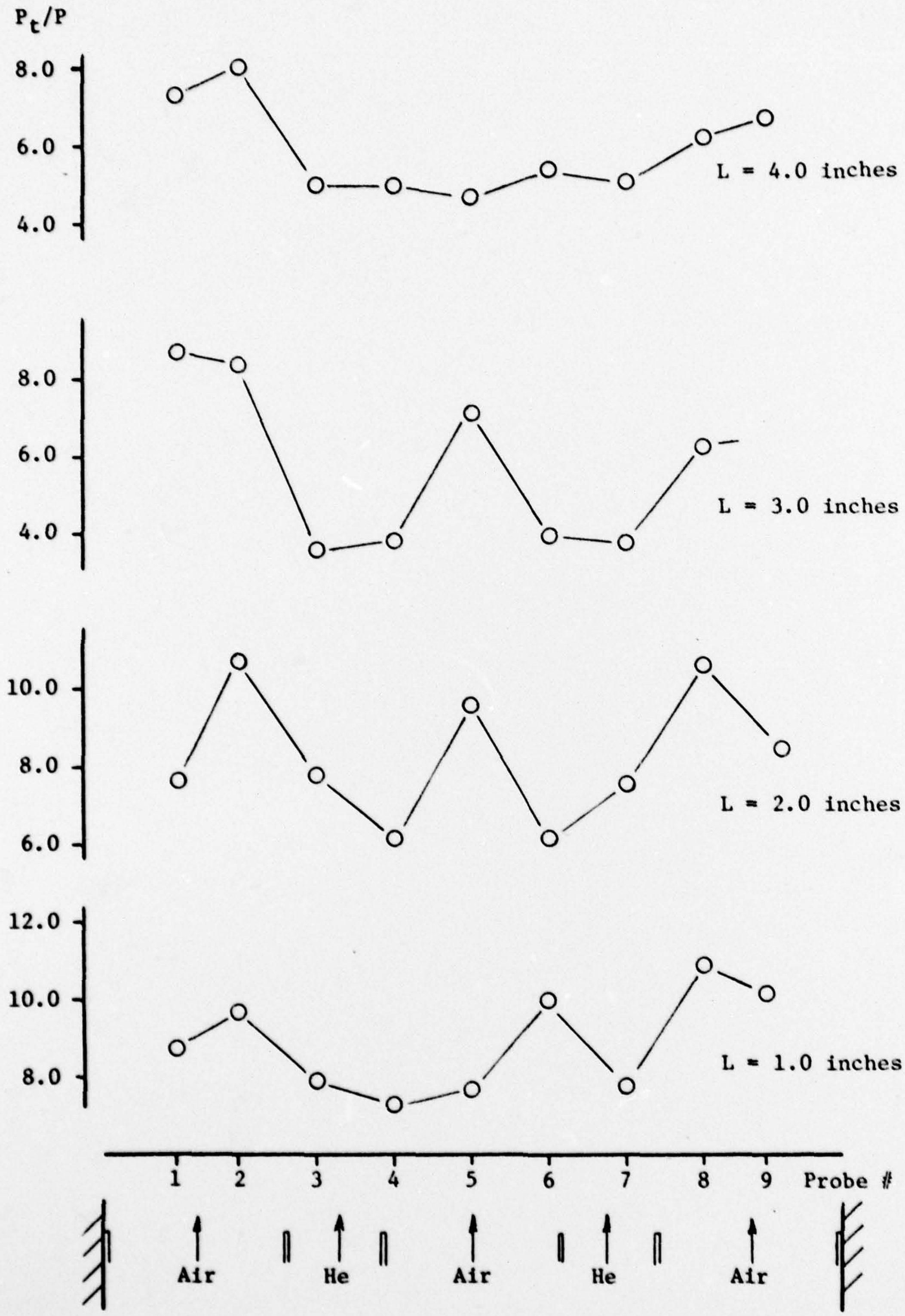


Fig. 17. P_t/P Variation, $P_{o\ Air}$ = 50 psig, $P_{o\ He}$ = 75 in Hg

Data Points are Mean Values from 17 Test Runs

Runs at $P_{o\ Air}$ = 65 psig, 80 psig

O - Flow Assumed to be 100% Air

Δ - Flow Assumed to be 100% He

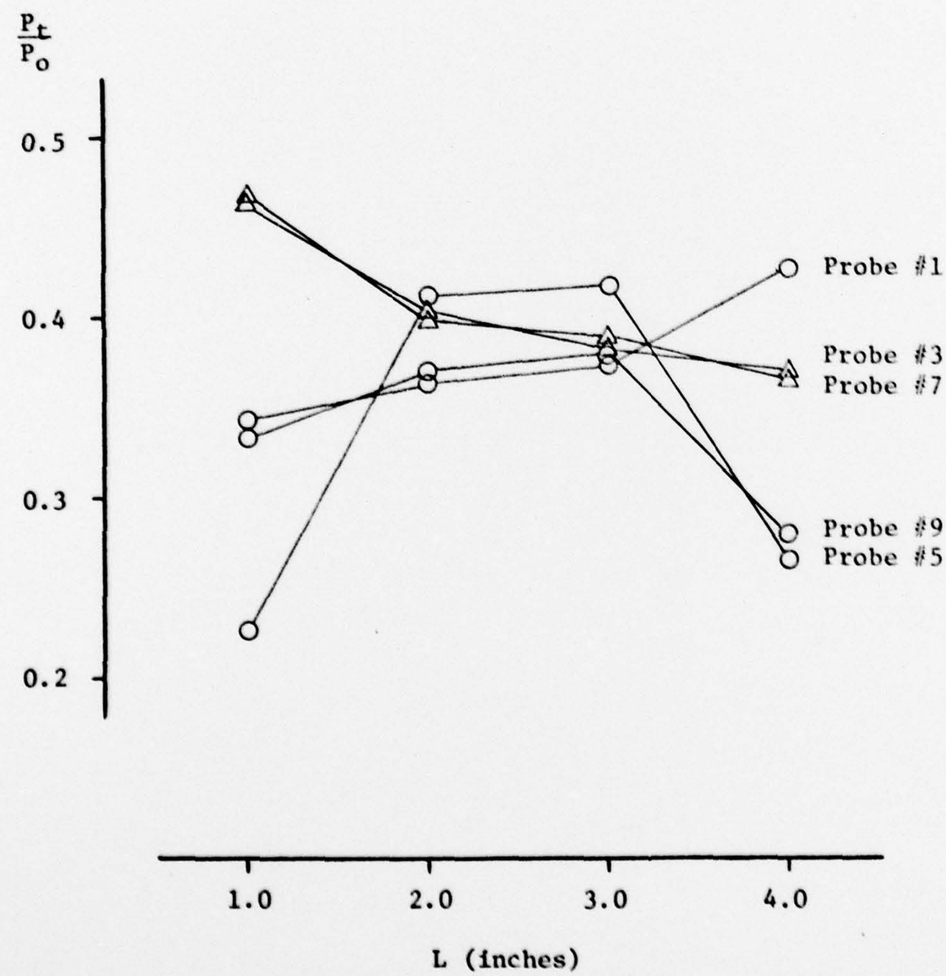


Fig. 18. Variation of P_t/P_o Within the Flow Field

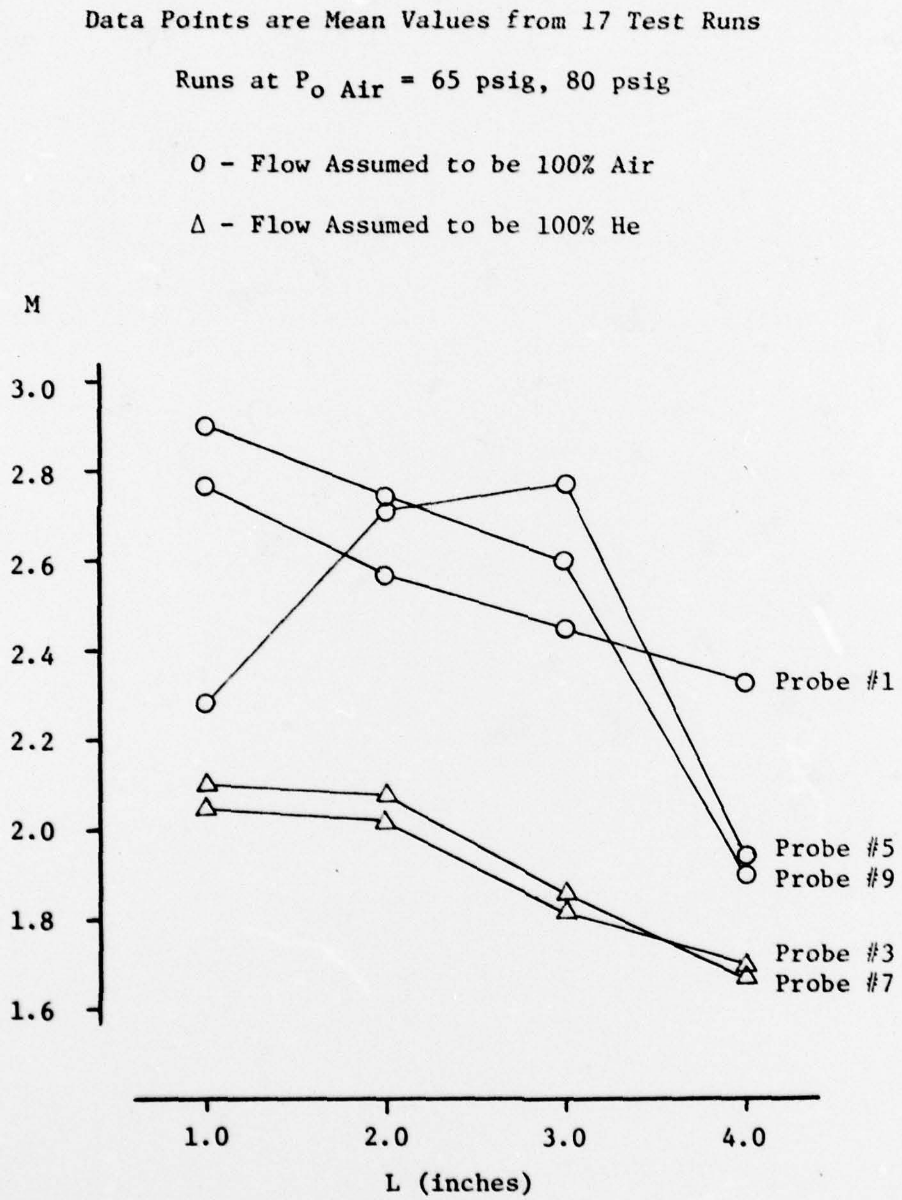


Fig. 19. Variation of Mach Number Within the Flow Field

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APPENDIX A

PRESSURE VARIATION

WITHIN THE TEST CAVITY

TABLE I

Pressure Variation in the Test Cavity

$P_{o\ Air} = 80$ psig

Static Pressure (psia)

Position No.	L (Inches) 1	2	3	4
1.	2.90	3.75	4.23	5.12
2.	3.26	3.13	4.18	3.92
3.	3.77	3.45	3.93	4.29
4.	3.79	3.48	3.84	4.75
5.	2.88	3.85	3.93	4.39
6.	3.44	3.90	4.13	4.41
7.	3.58	3.26	3.89	4.31
8.	3.02	3.13	3.98	4.90
9.	2.71	3.28	-	-

Total Pressure (psia)

Position No.	L (Inches) 1	2	3	4
1.	32.28	33.85	26.13	37.27
2.	29.56	36.31	28.44	25.40
3.	24.35	21.14	10.96	20.13
4.	33.58	21.95	13.46	25.31
5.	21.27	38.23	30.70	24.97
6.	34.04	23.61	15.82	25.58
7.	24.35	20.71	11.55	19.64
8.	29.54	35.77	27.51	31.82
9.	31.41	33.63	26.53	25.14

Pressures are mean values from 9 test runs

TABLE II

Pressure Variation in the Test Cavity

$P_{o\ Air}$ = 65 psig

Static Pressure (psia)

Position No.	L (Inches) 1	2	3	4
1.	2.85	3.31	3.69	4.68
2.	2.76	2.81	3.64	3.53
3.	3.15	2.94	3.39	3.85
4.	3.20	3.16	3.34	4.17
5.	2.61	3.36	3.10	4.04
6.	3.00	3.38	3.59	3.94
7.	3.20	2.77	3.30	3.87
8.	2.51	2.84	3.44	4.02
9.	2.41	2.86	3.30	-

Total Pressure (psia)

Position No.	L (Inches) 1	2	3	4
1.	27.46	29.48	29.62	36.02
2.	26.18	31.72	36.30	30.71
3.	22.65	19.96	18.87	18.19
4.	26.77	19.76	19.11	21.36
5.	18.13	33.49	32.86	21.01
6.	29.52	21.16	20.63	22.22
7.	22.70	20.05	19.16	10.06
8.	26.43	31.23	32.81	28.53
9.	26.63	29.19	30.16	23.05

Pressures are mean values from 6 test runs

TABLE III

Pressure Variation in the Test Cavity

P_o Air = 50 psig

Static Pressure (psia)

Position No.	L (Inches) 1	2	3	4
1.	2.49	3.21	4.92	4.09
2.	2.29	2.35	4.87	3.04
3.	2.66	2.42	5.56	3.28
4.	2.36	2.71	5.11	3.63
5.	2.49	2.77	4.72	3.50
6.	2.36	2.76	5.41	3.43
7.	2.69	2.40	5.75	3.28
8.	2.07	2.35	5.16	3.55
9.	2.12	2.79	-	3.68

Total Pressure (psia)

Position No.	L (Inches) 1	2	3	4
1.	22.09	24.70	42.88	30.05
2.	22.28	25.28	40.97	24.55
3.	20.96	18.93	20.19	16.35
4.	17.22	16.69	19.65	17.82
5.	19.19	26.66	33.80	16.57
6.	23.71	17.18	21.67	18.56
7.	20.95	18.21	21.86	16.74
8.	22.50	25.04	32.27	22.29
9.	21.67	23.79	43.77	24.74

Pressures are mean values from 7 test runs

Vita

John D. Carlile was born 5 January 1946 in Great Bend, Kansas, the son of George E. and Ruby M. Carlile. He graduated from the University of Kansas in 1969 with a Bachelor of Science degree in Aerospace Engineering. He was employed as an associate engineer in the aerodynamics department of the McDonnel-Douglas Corporation at St. Louis, Missouri, until entering Officer Training School in 1970. He completed Navigator training at Mather AFB, California, F-4 Weapons System Officer training at George AFB, California, and flew 235 combat missions from Ubon Royal Thai Air Base, Thailand. He entered the Air Force Institute of Technology from an assignment as an Instructor Weapons System Officer at Bitburg Air Base, Germany. He completed a Master of Science degree in Human Resource Management from the University of Utah extension program in Germany in 1976. His assignment upon completion of the AFIT program is at Los Angeles Air Station, California, as a space shuttle flight test manager.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A facility to study two-dimensional supersonic air-helium mixing in a gas dynamic laser cavity was designed, constructed, and evaluated. The flow field may be analyzed via static and total pressure measurements, gas mixture samples, and schlieren photography. The multiple nozzle test section consisted of Mach 3.0 air nozzles alternated with Mach 3.0 helium nozzles exhausted into an instrumented test cavity. Pressure was maintained in the cavity by two alternate methods; simple diffusers exhausted to atmospheric conditions, and exhausting the cavity into a group of evaculated air tanks.

Both methods gave similar cavity flow fields as indicated by schlieren photography and static pressure measurements. Gas samples and pressure measurements were taken with a series of small diameter probes and automatically timed solenoid valves. Gas samples were not analyzed in this study. Nozzle exit plane Mach numbers were calculated from pressure measurements and verified with schlieren photographs of a wedge inserted into the flow. The apparatus has low helium consumption and yields accurate, repeatable pressure measurements. The facility is to be used for a subsequent complete flow field analysis.